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PROCEEDINGS.

Seven hundred and ninety-third Meeting.

May 25, 1886. — ANNUAL MEETING.

The PRESIDENT in the chair.

The President announced the death of Leopold von Ranke, Foreign Honorary Member ; and of Charles Edward Hamlin and Charles Upham Shepard, Resident Fellows.

The Corresponding Secretary read a letter from Mr. Richard S. Greenough, announcing the shipment of a portrait of Galileo as a gift to the Academy.

On the motion of the Corresponding Secretary, it was

Voted, To meet, on adjournment, on June 16, 1886.

The reports of the Council and of the Librarian were read and accepted.

The report of the Rumford Committee was read and accepted, as follows : —

The Rumford Committee present the following report of what has been done by them since the last annual meeting of the Academy.

The committee approved bills amounting to \$447.49 for printing in the Proceedings all the papers which related to Light and Heat.

In June, 1885, \$1000 was voted by the Academy for the use of the committee in encouraging investigations upon Light and Heat. Of this sum, \$300 was put at the disposal of Prof. E. C. Pickering, to assist in the continuation of his great work on stellar photometry and photography. The same sum (\$300) was allowed to Mr. W. H. Pickering, to aid him in the prosecution of his work on dry-plate photo-

graphing, and for a research on a new standard of light. The unexpended balance of the \$1000 (viz. \$400) will revert to the treasury.

It was voted to recommend to the Academy the appropriation of \$500 from the income of the Rumford Fund for the construction and mounting of instruments to be used by Mr. W. H. Pickering in observations upon the solar corona at the time of the total eclipse of the sun, on August 28, 1886. The other expenses of the expedition to the West Indies for this purpose will be paid by the members of the party.

The committee think that the time has come for making another award of the Rumford Premium. They have spent much time in weighing carefully the claims of several candidates, all of whom are of great merit. After careful consideration of the subject, they have voted unanimously to recommend to the Academy that the Rumford Premium be awarded to Prof. S. P. Langley, of Allegheny Observatory, for his researches on radiant energy. To carry out the objects of this report, the committee recommend the adoption of the votes appended to this report.

Respectfully for the committee,

J. LOVERING, *Chairman.*

May 25, 1886.

In accordance with the recommendation of the Rumford Committee, it was

Voted, That the Rumford Premium be awarded to Prof. S. P. Langley for his researches on radiant energy.

Voted, That the Treasurer be authorized to pay from the income of the Rumford Fund the sum required for the preparation of the gold and silver medals to be presented to Professor Langley.

Voted, That the Treasurer be authorized to pay from the income of the Rumford Fund \$500 for the construction and mounting of instruments to be used in observations of the solar corona at some appropriate station in the West Indies during the solar eclipse of August 28, 1886.

The following appropriations were voted : —

For general expenses	\$2,200.00
For publications	2,000.00
For the library	1,226.45

The annual election resulted in the choice of the following officers : —

JOSEPH LOVERING, *President*.
 OLIVER W. HOLMES, *Vice-President*.
 JOSIAH P. COOKE, *Corresponding Secretary*.
 WILLIAM WATSON, *Recording Secretary*.
 AUGUSTUS LOWELL, *Treasurer*.
 HENRY W. HAYNES, *Librarian*.

Council.

WOLCOTT GIBBS,	} of Class I.
CHARLES L. JACKSON,	
CHARLES R. CROSS,	
BENJAMIN E. COTTING,	} of Class II.
SERENO WATSON,	
ASA GRAY,	
ANDREW P. PEABODY,	} of Class III.
JOHN C. ROPES,	
FREDERICK W. PUTNAM,	

Rumford Committee.

WOLCOTT GIBBS,	JOSIAH P. COOKE,
EDWARD C. PICKERING,	JOSEPH LOVERING,
JOHN TROWBRIDGE,	GEORGE B. CLARK,
ERASMUS D. LEAVITT, JR.	

Member of the Committee of Finance.

THOMAS T. BOUVÉ.

The President appointed the following standing committees:—

Committee of Publication.

JOSIAH P. COOKE, ALEXANDER AGASSIZ,
ASA GRAY.

Committee on the Library.

HENRY P. BOWDITCH, AMOS E. DOLBEAR,
BENJAMIN A. GOULD.

Auditing Committee.

HENRY G. DENNY, THOMAS T. BOUVÉ.

Seven hundred and ninety-fourth Meeting.

June 16, 1886. — ADJOURNED ANNUAL MEETING.

The PRESIDENT in the chair.

The report of the Treasurer was read and accepted.

Since it had been questioned whether a quorum was present at the annual meeting of May 25, 1886, it was

Voted, To confirm and approve the votes and ballots then taken and declared.

It was also

Voted, To amend the statutes of the Academy by inserting the words "the Librarian" after the word "Treasurer," in Chapter II., paragraph 2.

Professor Cross read the following papers:—

Some Experiments relating to the Melting Platinum Standard of Light. By Charles R. Cross.

The Inverse Electromotive Force of the Voltaic Arc. By Charles R. Cross and William E. Shepard.

The Efficiency of small Electro-motors. By H. E. H. Clifford and S. D. Bartlett.

Professor William M. Davis made a verbal statement on the probable vertical distribution of temperature and pressure in thunder-storms, illustrating it by a vertical section showing isothermal and isobaric lines.

The following papers were presented by title : —

On a Form of a combined Yard and Meter adapted for the exact Determination of the Relation between the Lengths of these standard Units. By William A. Rogers.

Contributions from the Cryptogramic Laboratory of Harvard University: I. On the Anatomy and Development of *Agarum Turneri*, Post. & Rupr. By James E. Humphrey. II. On the Morphology of *Ravenelia glandulæformis*. By G. H. Parker.

Seven hundred and ninety-fifth Meeting.

October 13, 1886. — STATED MEETING.

The PRESIDENT in the chair.

The President announced the death of Ephraim Whitman Gurney, William Ripley Nichols, Charles Callahan Perkins, and Henry Hobson Richardson, Resident Fellows.

Oliver Whipple Huntington, of Cambridge, was elected a Resident Fellow in Class I., Section 3.

The Corresponding Secretary read the following letters: from M. Lacaze-Duthiers, acknowledging his election as Foreign Honorary Member; from the President of the University of Japan, announcing the foundation of the University; from the Superintendent of the United States Naval Observatory, in relation to the publication of its meteorological observations.

A circular from the American Committee of the International Congress of Geologists, requesting the Academy to unite with other societies in inviting this Congress to hold its next meeting in the United States, was also read; and it was thereupon

Voted, That the President be authorized to sign, on behalf of the Academy, the invitation to be addressed to the International Congress of Geologists.

On the motion of the Corresponding Secretary, it was

Voted, That the thanks of the Academy be presented to Mr. Richard S. Greenough for his valuable present of the portrait of Galileo.

A biographical notice of Henry Hobson Richardson, by the Rev. Phillips Brooks, was read by the Corresponding Secretary.

Seven hundred and ninety-sixth Meeting.

November 10, 1886. — MONTHLY MEETING.

The PRESIDENT in the chair.

Professor Pickering presented a paper entitled, —

Observations of the Light of the Stars. By Paul Stroobant.

Remarks were made by Professors Samuel P. Langley, Charles A. Young, and E. C. Pickering upon the wedge photometer, and the subject was discussed at length by Messrs. Davis, W. H. Pickering, A. Hall, Peters, and Edmands.

Professor Cleveland Abbe alluded to the experiments on ventilation described by Dr. Morrill Wyman.

Seven hundred and ninety-seventh Meeting.

December 8, 1886. — MONTHLY MEETING.

The PRESIDENT in the chair.

Professor Farlow presented, by title, a communication entitled, —

On certain Cultures of Gymnosporangium, with Notes on certain Ræstelæ. By Roland Thaxter.

Mr. Sereno Watson presented, by title, the following: —

Contributions to North American Botany: Revisions of Portulacaceæ, Malvaceæ, etc., with some Miscellanea. By Asa Gray.

Seven hundred and ninety-eighth Meeting.

January 12, 1887. — STATED MEETING.

The PRESIDENT in the chair.

The Rumford Committee submitted a report recommending several appropriations from the income of the Rumford Fund, and it was accordingly

Voted, That an appropriation of five hundred dollars (\$500) be made to assist Professor H. P. Bowditch in calorimetric researches on the heat of the human body.

Voted, That an appropriation of two hundred and fifty dollars (\$250) be made to Professor Trowbridge, to aid in his researches on radiant energy.

Voted, That an appropriation of seventy-five dollars (\$75) be made to Professor Cross, to aid in his researches on the influence of thermo-electric currents and other thermal actions upon the accuracy of the Munich shunt method of measuring very strong currents of electricity.

Voted, That an appropriation of two hundred and fifty dollars (\$250) be made to Professors Cross and Holman to aid them in their researches on thermometry.

On the motion of the Librarian, it was

Voted, To appropriate one hundred dollars (\$100) for the rent of the alcoves in the reading-room of the Athenæum; also, to appropriate one hundred and ten dollars (\$110) for shelving an additional alcove.

The following papers were presented:—

On the Acceleration of Gravity at the Harvard Physical Laboratory. By Edwin H. Hall.

On new Methods for observing the Action of Colored Liquids on Living Protoplasm. By George L. Goodale.

Seven hundred and ninety-ninth Meeting.

February 9, 1887. — MONTHLY MEETING.

The PRESIDENT in the chair.

The following papers were presented:—

On the Coahuila Meteorites. By Oliver W. Huntington.

The Chinook Wind, and its Effect on the Isotherms and Isobars of the daily Weather Map. By William M. Davis.

Eight hundredth Meeting.

March 9, 1887. — STATED MEETING.

The PRESIDENT in the chair.

The following gentlemen were elected members of the Academy: —

John Ritchie, Jr., of Boston, to be a Resident Fellow in Class I., Section 2.

Thomas Messenger Drown, of Boston, to be a Resident Fellow in Class I., Section 3.

Jesse Walter Fewkes, of Cambridge, to be a Resident Fellow in Class II., Section 3.

David Gordon Lyon, of Cambridge, to be a Resident Fellow in Class III., Section 2.

Joseph Henry Thayer, of Cambridge, to be a Resident Fellow in Class III., Section 2.

Edward Jackson Lowell, of Boston, to be a Resident Fellow in Class III., Section 3.

Martin Brimmer, of Boston, to be a Resident Fellow in Class III., Section 4.

William Edward Story, of Baltimore, to be an Associate Fellow in Class I., Section 1.

George Davidson, of San Francisco, to be an Associate Fellow in Class I., Section 2.

Matthew Carey Lea, of Philadelphia, to be an Associate Fellow in Class I., Section 3.

John Newton, of New York, to be an Associate Fellow in Class I., Section 4.

John Strong Newberry, of New York, to be an Associate Fellow in Class II., Section 1.

John Wesley Powell, of Washington, to be an Associate Fellow in Class II., Section 1.

Daniel Cady Eaton, of New Haven, to be an Associate Fellow in Class II., Section 2.

Joel Asaph Allen, of New York, to be an Associate Fellow in Class II., Section 3.

Addison Emery Verrill, of New Haven, to be an Associate Fellow in Class II., Section 3.

Horatio C. Wood, of Philadelphia, to be an Associate Fellow in Class II., Section 3.

Henry Adams, of Washington, to be an Associate Fellow in Class III., Section 3.

William Robert Ware, of New York, to be an Associate Fellow in Class III., Section 4.

The following papers were presented : —

On new General Reactions with Sodiumacetacetic and Sodium-malonic Ethers. By Arthur Michael.

Observations of Variable Stars in 1886. By Edward C. Pickering.

Professor Cross presented the following papers : —

The Efficiency of small Electro-motors. By H. E. H. Clifford.

On Tests of a Commercial Storage-Battery. By Edward E. Higgins.

Professor Jackson presented, by title, the following papers : —

On Benzoltrisulphonic Acid. By C. Loring Jackson and John F. Wing.

On the Action of Nitric Acid on Symmetrical Trichlorbenzol. By C. Loring Jackson and John F. Wing.

Professor Pickering called attention to the circular concerning the Boyden Fund issued by the Harvard College Observatory.

Eight hundred and first Meeting.

April 13, 1887. — MONTHLY MEETING.

The Academy met at the Peabody Museum of American Archæology and Ethnology, Cambridge.

The PRESIDENT in the chair.

The Corresponding Secretary announced that he had received letters from Messrs. Thomas M. Drown, Edward J.

Lowell, David G. Lyon, and Joseph H. Thayer, acknowledging election as Resident Fellows; and from Messrs. Henry Adams, George Davidson, Daniel C. Eaton, M. Carey Lea, John S. Newberry, John Newton, John W. Powell, William E. Story, and Horatio C. Wood, acknowledging election as Associate Fellows.

The President announced the death of Professor August Wilhelm Eichler.

The President announced that he had accepted, in the name of the Academy, the invitation to send a delegate to the centennial celebration of Columbia College.

Professor Frederick W. Putnam presented a paper, entitled, —

“Account of Explorations in Ohio, with Special Reference to the Discovery of Objects made of native Copper, Silver, Gold, and Iron in the Mounds.”

The following papers were presented by title: —

Contributions to American Botany: I. Notes upon some Genera of Coniferæ. II. List of a Collection of Plants made in the State of Jalisco, Mexico, by Dr. Edward Palmer, in 1886. III. Descriptions of New Species of Plants from the Western United States and Chihuahua. By Sereno Watson.

Eight hundred and second Meeting.

May 11, 1887. — MONTHLY MEETING.

The Academy met at the house of the Recording Secretary, 107 Marlborough Street.

The PRESIDENT in the chair.

The President invited the attention of the Fellows to the special object of the meeting, which was the presentation of the Rumford Medals which had been voted to Professor S. P. Langley, at the last annual meeting, for his researches on radiant energy. He was happy to see so large an attendance of Fellows to welcome Professor Langley, as he

had honored the Academy by coming from his distant home to receive the medals in person. Before presenting the medals, he asked the indulgence of the Academy while he gave a hasty sketch of the work which had won for Professor Langley the award of the Rumford Premium.

The progress of science, by enlarging our ideas of the complex operations of nature, has introduced a new phraseology for describing them which would be unintelligible to men of a former generation. The chemistry of the sun and astro-physics would have had no meaning for them. Formerly, the two great divisions of Astronomy were designated as Practical and Physical; Physical Astronomy being limited to the mathematical development of the law of gravitation. The application of physical instruments, such as the thermo-electric thermometer, the spectroscope, the phosphoroscope, and the photographic camera, — all now common servants of astronomy, — to the analysis of the luminous, calorific, and chemical radiations from the sun, has given a wider meaning to Physical Astronomy; so that what was once understood by that phrase may be more properly called mathematical or mechanical astronomy, — the *Mécanique Céleste* of Laplace.

Long familiarity with the facts of gravitation has made science insensible to its mysterious mode of action; although the labors of Faraday and Maxwell make it improbable that it acts independently of a material medium between the attracting bodies. On the other hand, the radiations of light and heat have been brought completely under the control of the theory of undulations. While the intensity of light depends partly on the physiological adaptation of the eye, radiant energy can be revealed to physical instruments capable of measuring the amount of heat which is emitted. Thermo-electricity was discovered by Seebeck, of Berlin, in 1821. In 1834, Melloni constructed his highly sensitive thermo-electric thermometer (called the thermo-multiplier), by means of which he proved that the laws of reflection, refraction, dispersion, absorption, interference, and polarization apply to heat as well as to light, and that the theory of undulations is as true of one as of the other.

While astronomy was winning new victories every year in studying the motions of the heavenly bodies, there seemed to be no hope that it could ever detect the motion of a star in the line of vision, as its disk is immeasurably small and a spurious one. Great interest was felt, therefore, in the attempts of Huggins and others to solve this problem

by the displacement of the dark lines in the stellar spectrum. The validity of the theory of this displacement was tested by applying it to the eastern and western edges of the sun's equator, which are moving opposite ways with a known velocity. Professor Langley's plan of testing the validity of his instrument, by taking the light first from the two poles of the sun and then from the two edges of the equator, was ingenious and convincing. What he did on this problem told incidentally in his researches on radiant energy, assuring him of the superiority in dispersive power of Rutherford's fine gratings over the most powerful battery of prisms. Moreover his visit to Mount Ætna, in 1878, enabled him afterwards to make a happy selection of a station for his mountain observations.

When Professor Langley began his work on solar energy, he found that the thermo-multiplier did not give reliable results. In 1851 Svanberg had described in a volume of the *Poggendorff Annalen* a new method of measuring heat by applying it so as to disturb the electrical balance in Wheatstone's bridge, and he expressed the hope that the new instrument would be found to rival, if not to exceed in delicacy, the thermo-multipliers of Nobili and Melloni. This was the only hint which Professor Langley had in the invention of his famous instrument, the spectro-bolometer, the first description of which was published in the Proceedings of this Academy for 1881. At that time the instrument was from ten to thirty times more sensitive than the thermo-multiplier, acted more promptly, and gave measurable results. Even the heat of the moon, on which the largest telescopes had pronounced with no certain sound, surrendered to the touch of the bolometer.

Physicists were generally of the opinion that light and heat were transmitted by separate undulations, or at least were independent properties of the same undulation, as the maximum of light in the prismatic spectrum is in or near the yellow, while the maximum of heat is outside of the red. Dr. J. W. Draper predicted that the two maxima would coincide in a normal spectrum, produced by a diffraction grating. But the heat from the grating was too small to be measured by any instruments at his command, and he was able to verify his prediction only to the extent of showing that the total heats on the two halves of this spectrum were equal. At this juncture, Professor Langley entered the field with his bolometer. He had at his command two of Rutherford's gratings, ruled upon metal; one having 17206 lines to the inch (or 681 to the millimeter), the other having half of that number. The rays from the grating fell upon a

concave mirror, and were concentrated upon the bolometer. The deviation of the rays was measured by a divided circle, and the wave-lengths calculated. No collimator was used, and there was no absorption except by the atmospheres of the sun and the earth. The absorption by the earth's atmosphere was calculated by comparing noon observations with those taken near to sunrise and sunset. The absorption of violet light was great, and of the most luminous rays greater than for red light or the infra-red waves. The inference was drawn that outside of our atmosphere the sun would be bluish.

Armed with his new and powerful instrument of research, Professor Langley went on a scientific expedition to Mt. Whitney, in Southern California, in 1881, with the purpose of measuring the solar constant of radiation and the absorption produced by the earth's atmosphere; occupying, successively, three stations at 800, 4000, and 4800 meters of elevation, where the rarity and dryness of the air promised a greater degree of accuracy in his work. Observations were made with the actinometer of Violle and the pyrheliometer of Pouillet synchronously with those of the bolometer. With a Hilger glass prism of the finest quality and workmanship and a Rutherford grating, for the prismatic and normal spectra, the bolometer revealed to his intellectual eye a region of invisible solar activity outside of the red greater than that which the eye had ever seen.

On his return to the Allegheny Observatory he found that he could continue his work at this lower level with advantage, since his study of atmospheric absorption enabled him to eliminate its influence upon his measurements. He corrected the errors introduced into the prismatic spectrum by the absorption of a glass prism, by repeating the observations with prisms of rock-salt, fluor-spar, and quartz. In the spring of 1882 he repeated his work upon the normal spectrum with one of Professor Rowland's admirable gratings ruled upon a concave surface of metal. It contained 18050 lines, 142 to the millimeter, and exposed a ruled surface of 129 centimeters. Being of short focus, it gave a specially hot spectrum.

The general conclusions which had been reached were these: that light, heat, and chemical action coincided in the curves which expressed the distribution of these various forms of energy; that absorption was inversely as the wave-length; that the greater energy in the luminous region was there in spite of its greater absorption; that the maximum energy was near the yellow; and that the new district which had been added to the normal spectrum was greater than the visible and invisible spectrum which had been known before. Moreover, the general

continuity of the curve of energy was broken at several places by deep valleys, indicating the presence of cold bands instead of hot ones.

At this stage of his investigation Professor Langley encountered a most delicate and difficult problem. The prism furnishes the most heat; the grating gives the wave-length; but the laws of refraction and dispersion necessarily distort the prismatic spectrum, and lead to false conclusions in regard to the distribution of solar energy. Professor Langley happily combined the grating and prism so as to be able to translate the prismatic spectrum into the normal spectrum. He had here to deal with three unknown quantities, viz. the prismatic deviation, the index of refraction, and the wave-length. The relation between this deviation and the index of refraction is well established. The relation between this deviation and the wave-length is obscured by theoretical and mathematical difficulties. This relation has been expressed by various formulas, derived from the undulatory theory of light, and involving preconceived ideas in regard to the atomic constitution of the luminiferous ether. A fair criticism can be passed upon these formulas, that they disagree with each other, and, in extreme cases, involve results which are contradicted by observation. All of them are expressed by a descending series of terms, involving many constants which must be determined by observations made within a limited range of the visible spectrum. Professor Langley undertook to solve the problem experimentally by a happy combination of a grating and a prism.

If the deviation of a homogeneous ray by a grating is observed, the corresponding wave-length is given by a simple rule. Within the limits of visibility there is no difficulty. Outside of these limits, the diffraction deviation must be indicated by heat-energy; and that becomes insufficient with the Rutherford gratings in the extreme parts of the infra-red. But the concentrated heat from one of Rowland's exquisite gratings affects the delicate strips of the latest bolometers even in the longest wave-lengths. Professor Langley's experimental devices in this case were beautifully complex. Rays were condensed upon a fine slit, and then went to the grating. Those of definite wave-lengths were accumulated upon a second slit, and formed there a sharp spectrum. Invisible spectra were superimposed at this slit upon the visible spectrum; but their wave-lengths were simple multiples of the wave-lengths of the visible spectrum. This compound spectrum was sent next through a prism, and its components deployed out into separate columns. The prismatic deviation of the visible spectrum was measured with the eye. By groping with the bolometer in the dark

for the invisible ones their deviation was measured, and therefore their indices of refraction. Two results were reached: 1. The relation between the wave-length and the index of refraction for the invisible rays was determined experimentally: 2. The validity of the theoretical formulas of Cauchy, Redtenbacher, Briot, and Wüllner for expressing this relation was confronted with the facts of observation, in order to discover which of them were most trustworthy, and within what limits the best could be safely used.

In August, 1886, Professor Langley published a paper on "Hitherto unrecognized Wave-Lengths," in which he describes a modification in the bolometer arrangement by which it was adapted to the electric light. His latest refinements on the bolometer, supplemented by an improved Thomson galvanometer for measuring its indications, have culminated in an instrument capable of revealing the presence of one millionth of a Centigrade degree, and of giving reliable measures down to the hundred-thousandth of a degree. He gives additional observations on wave-lengths, deviations, and indices of refraction, made with three different gratings of Rowland, and with lenses and prisms of rock-salt in place of glass. In applying the formulas for dispersion the constants must be determined by observations with highly dispersive prisms. This was first done by Professor Baden Powell of Oxford. Adopting Cauchy's formula, he came to the conclusion that the greater wave-lengths converged towards a constant value, and that the maximum value was not far beyond the red. Professor Langley has compared his experimental results with the various formulas which assign the relation between wave-length and the index of refraction, and has come to the conclusion that, while there is great choice between them, no one of them can be trusted in its application to wave-lengths which are far beyond the visible spectrum.

This paper concludes with an interesting summary of the extreme range in the length of heat-waves, as given by the eye alone, or by the united aid of phosphorescence, photography, and the bolometer. While Newton's scale of wave-lengths had a compass of less than an octave, which others in recent times have extended, somewhat doubtfully, to about an octave and one half, the bolometer in the hands of Professor Langley has ranged over eight times the length of Newton's spectrum by actual measurement, and has indicated the existence of energy in a field six times greater for some kind of heat. In one sense Professor Langley has bridged over the gulf between the shortest wave-length of sound and the longest wave-length of heat. If, however, he should succeed, as he certainly may, in discovering waves

of heat as long as the shortest waves of sound, the broadest chasm will still remain open ; for the rapidity of undulation of these longest waves of heat will exceed that of the shortest waves of sound as many times as the velocity of light is greater than the velocity of sound. And we must still ask the question, What use has nature, with her economy of means and her law of continuity, made of those fifty octaves, or thereabouts, which have no employment in heat or sound?

I have said nothing of the most recent work of Professor Langley on the solar-lunar energy, hoping that he himself may be willing to address you upon that subject.

To what, now, shall we say that science is indebted for the startling results which I have hastily and imperfectly presented to you? Is it to the bolometer? That led to no discoveries in the hands of its first inventor, and remained unknown and useless, with one slight exception, for nearly thirty years. No doubt, Professor Langley improved vastly upon the original delicacy of the bolometer ; but still it was only an instrument of wonderful precision, demanding all the more skill in him who used it. Therefore, we owe the discoveries which I have attempted to describe to the intelligence which was behind the instrument ; to the perseverance and courage which were disheartened by no difficulties ; to the originality which Professor Langley displayed in the complex combinations of the most delicate apparatus ; to the enthusiasm which brought to his aid all the appliances of science and art from the highest sources ; and to the confidence which he inspired in academies and private friends, so that his work might not languish for want of funds.

And now, Professor Langley, it is my most agreeable duty and privilege to present to you, in the name of the American Academy, and in the presence of these numerous Academicians who are here assembled to administer Count Rumford's trust, the gold and the silver medals, which together make the Rumford Premium. Be pleased to accept, with these medals, my hearty congratulations, and the warm felicitations of all the members of this Academy, for the brilliant results with which your long and patient work on Solar Energy has been crowned.

Professor Langley, on receiving the medals, made the following reply :—

MR. PRESIDENT, — My labors have met with kind recognition before, but with none that has touched me so nearly as the present, which I receive in the city of my birth at the hands of those many of whose

names have been honored ones with me from my earliest years, and through you, to whom I have looked as a master in physical science since my boyhood. The thanks I would express through you to the Academy which has thus greatly honored me are very deeply felt.

As to the work I have done in connection with the subject of heat, I am glad to believe, on your assurance, that it is such as the great fore-caster of our modern physical doctrine of the subject would have approved; and it will, now and always, be a lasting gratification to me that it has been thus fortunate in being connected with the name of Count Rumford.

You have spoken of the labors that I have carried on; but when I remember that a later discoverer than Rumford tells us how, even as a little child, he was so impressed with the wonder and mystery of radiant heat, that he then dedicated his life to its study, I am glad to remember too, that, if I cannot resemble Melloni in the great results he achieved, I am at least happy in this, that the principal labors of my maturer life have been upon the plan which pleased my childish thought, so that these researches to which you allude have been to me a delight rather than a task.

The work then of which you speak has never seemed hard, or a thing to seek relief from, but always rather like a solace; and it is still something which I trust to follow through the rest of life, without needing any reward other than it brings in itself; though when there comes such approbation as yours, I can rejoice in it yet more.

Your kindness and the occasion will, I hope, gain indulgence for what is personal in that I have just said, and which is all I have to say, except that I would ask to be allowed to mention that the bolometer, to which you have specially alluded, was devised to meet an actual necessity. The most successful use of the thermopile demands at least as many years of apprenticeship as are given by the successful performer on a musical instrument; for the full results to be obtained from any such apparatus, which deal chiefly with invisible radiation, are only to be reached after such long and patient practice as few care to give.

I may say that I had already given more time to becoming familiar with what the thermopile could do, than it would have taken me to acquire another language, before I found myself unable to prosecute the research on the distribution of heat in the normal spectrum with it, so that I was perhaps then entitled to conclude that I had reached the limit of its sensitiveness. I gave, accordingly, nearly the whole

of another year to incessant experiment for the purpose of devising a more sensitive instrument than science then possessed. I cannot remember that I took the principle from any source then familiar to me ; but I think I was unconsciously guided by some dimly apprehended recollection of the electric pyrometer of Sir William Siemens, which I certainly had read of before.

When the bolometer was completed and in active work, I sought to get a knowledge of the literature of the subject (if it had a literature), and only then learned from my friend, Professor Rood, of the nearly forgotten paper by Svanberg, and which I believe I was the means of bringing to public notice in my first communication on the subject to the Academy.

At the request of the President, Professor Langley then went on to speak informally to the Academy of some as yet unpublished results of his work with the bolometer on the heat-spectrum of the moon.

The following papers were presented :—

Biographical Notice of the late Ephraim Whitman Gurney.
By Charles F. Dunbar.

The Law governing the Propagation of Signals in Electric Circuits. By William W. Jacques.

An Instrument for showing the forms of Undulatory Electric Currents. By William W. Jacques.

On the Spectrum of the Sun. By John Trowbridge.

The following papers were presented by title :—

Contributions from the Physical Laboratory of Harvard College : I. The Atmospheric Spectrum. II. On the Existence of certain Elements in the Sun. III. Radiation from Rock-Surfaces. IV. Efficiency of Secondary Generators. By John Trowbridge.

Reduction Factor of a Galvanometer Coil. By J. J. Skinner.